Near Real-Time Dissemination of Geo-Referenced Imagery by an Enterprise Server

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Abstract

NAVSYS has designed a GPS/inertial/video sensor (GI-Eye) that provides precision georegistration data of collected imagery directly at the sensor. This has been packaged into an Unmanned Air Vehicle (UAV) payload that generates precision mensurated imagery directly on the aircraft. The payload is connected through a data link to a ground-based server that can process the georegistered data in near-real-time using our GeoReferenced Information Manager (GRIM) Enterprise Server.

The GRIM Enterprise Server consists of a spatial database integrated with sophisticated search tools that allow for search and retrieval of sensor images that cover a common coordinate or a common point in a particular sensor image. These images can also be processed in near real-time to generate an automatic mosaic as the aircraft flies. This is produced in a format that Location Servers could access providing a near real-time Web view over the area covered by the aircraft using existing Web tools. In this paper, we describe the design of the GI-Eye sensor and GRIM Enterprise Server and present a demonstration of the type of imagery products that they can produce. We also describe a concept of operations for this technology.

Introduction

The use of georeferenced imagery across the Internet is becoming prevalent thanks to the development of web-based Location Servers such as Google Earth, TerraServer and Yahoo Local. One of the most frequently asked questions for these services is *"How old is your data?"* The answer posted by Google to this question is *"Google Earth acquires the best imagery available, most of which is approximately one to three years old."*[1] Users of these services are continually asking for more timely, high resolution data. The military also has a similar need to provide near real-time situational awareness to ground troops. This is currently provided using streaming video, but this does not provide the same geospatial awareness that the 3D Google Earth-like tools provide. Civil agencies such firefighters, search and rescue teams, law enforcement, 911 emergency operations, border patrol operations, traffic monitoring systems, and geological survey crews could also benefit from a near real-time web-based geospatial visualization capability.

To address this need for real-time geospatial awareness, NAVSYS has developed the GI-Eye product which includes the capability to generate precision mensurated imagery directly on the

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aircraft collecting the data. This has been combined with an Enterprise Server, termed the GeoReference Information Manager (GRIM) that uses this mensurated imagery to auto-generate mosaics as the data is being collected. With this approach, a near real-time geospatial view of the environment can be generated in a format that can be viewed using the current web-based geospatial visualization tools.

Benefits of Georegistered Imagery over Streaming Video

Currently, the military collects streaming video to provide real-time situational awareness over the battlefield. This video format requires high downlink bandwidths, and compression often results in grainy image quality. Also, the motion picture results are frequently unusable due to jitter and panning effects from the camera. They are also very difficult to interpret by an untrained user as they provide a “birds-eye” moving view from the air which is not easily referenced to spatial coordinates. While mensuration tools exist for streaming video, they are very computationally intensive and require extensive ground equipment.

The GI-Eye system integrates GPS, inertial and digital camera data to provide autonomous registration capability for imagery without requiring access to any Ground Control Points (GCPs). This provides real-time, high quality registered imagery at a 1-Hz rate. Using the GRIM server, this imagery can be rectified in near-real time and used to build a registered mosaic as shown in Figure 1. This has the advantage of providing stabilized, high resolution, near real-time imagery which can be viewed through existing Web software by untrained operators. For military and civil applications that require mensurated coordinates, these can be extracted from the registered mosaics through a simple “point and click” user interface. 3D models can also be built from the suite of images collected.

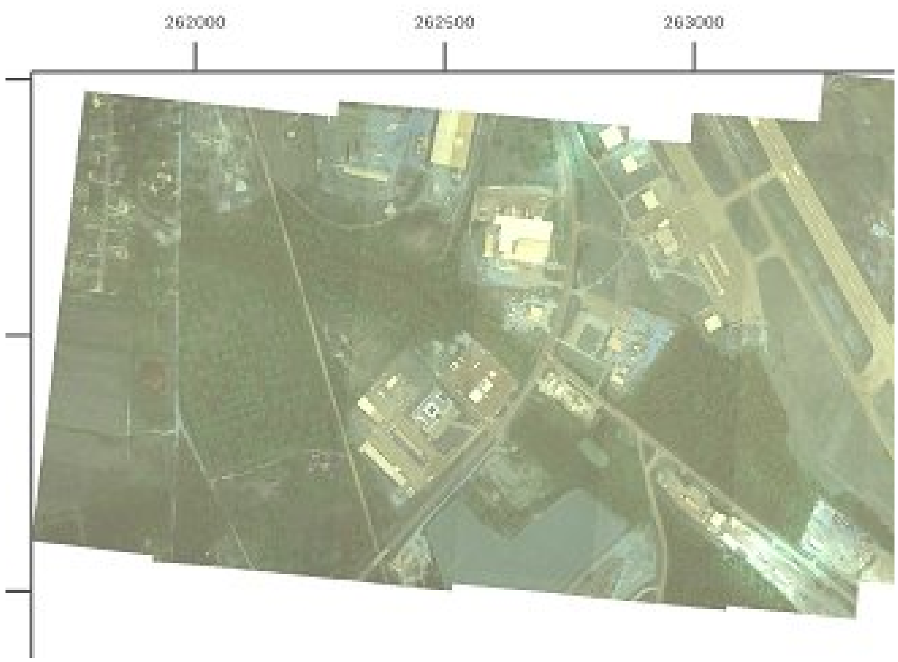

Figure 1 Rectified Mosaic

GI-Eye System Design

The GI-Eye product is offered to sensor manufacturers and systems integrators to provide an embedded precision autoregistration capability for electro-optic (EO), infra-red (IR) or other focal plane array (FPA) type sensors. This product has been integrated with a variety of different digital cameras and sensors. A ground-based system being used for tactical surveying and targeting by the National Geospatial-Intelligence Agency (NGA) is shown in Figure 2. GI-Eye is also being used by FLIR in their StarSAFIRE® III product (Figure 3) where it provides a GeoPointing[2] capability to stabilize their high resolution imaging to a point on the ground selected by the operator.

Figure 2 NGA Tactical Surveying and Targeting System (TS2)

Figure 3 FLIR StarSAFIRE III[3]

The GI-Eye product provides the capability to precisely time mark each camera image and uses NAVSYS' proprietary InterNav kinematic alignment algorithm[4] to measure the precise position and attitude of the camera using the GPS and inertial sensor data. The GI-Eye system auto-registration capability provides the location and pointing angle of the sensor with each image and also sensor calibration data from which the coordinates of each pixel in the image can be derived. This information can be used with a Digital Elevation Model (DEM) to extract the individual pixel coordinates of each image (Figure 4). It can also be used to derive a 3D DEM from multiple images through photogrammetry. With the precision GI-Eye meta-data, there is no need for any Ground Control Points (GCPs) to be used for image registration.

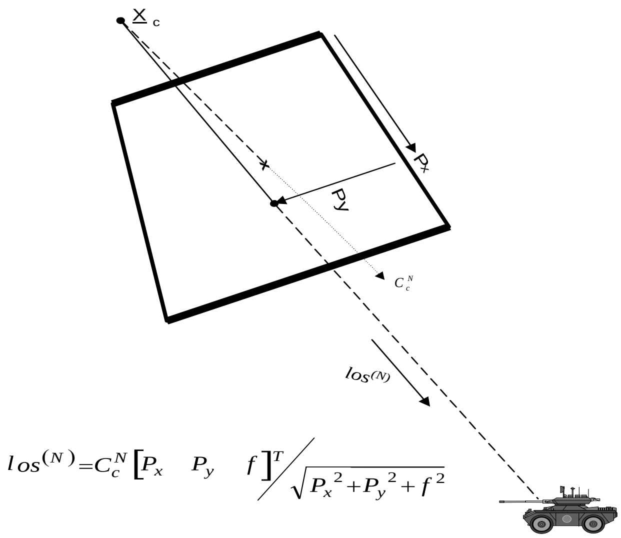

Figure 4 GI-Eye Position and Attitude Image Registration

NAVSYS' technology has resulted in improved position and attitude accuracy using relatively inexpensive inertial components. This allows georegistration accuracies of 1-2 meters to be provided when flying at an altitude of 1,000 feet without requiring the use of any ground truth[5].

GI-Eye Unmanned Air Vehicle (UAV) Payload

The GI-Eye has also been configured for use in a UAV payload. Our approach is to use a modular design that enables sensor upgrades over time with only software configuration changes. This allows us to take advantage quickly of advances in sensor and inertial subsystems. The GI-Eye system components are shown in Figure 5. From left to right, the figure shows the digital camera, power converter board, IMU interface board, single board computer, and the BAE Multisensor Inertial Measurement Unit (MIMU). The hard drive is positioned under the single board computer. In Figure 6 a drawing is shown of these components assembled in the ARES UAV payload. ARES is a small UAV developed by the Research and Engineering Center for Unmanned Vehicles (RECUV) group at the University of Colorado at Boulder for use in flight testing advanced unmanned air system concepts[6].

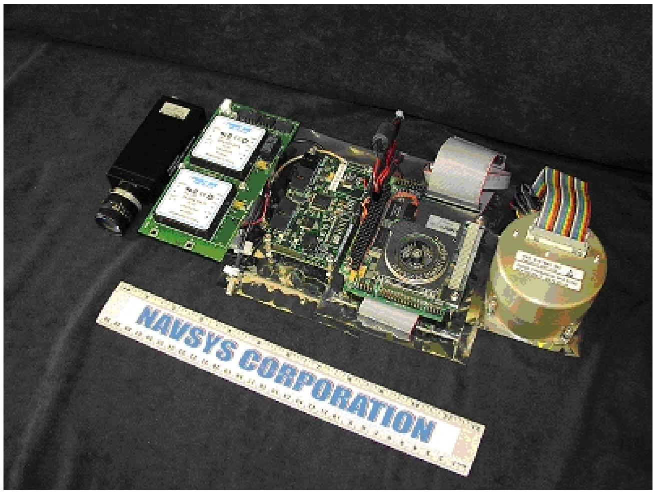

Figure 5 GI-Eye UAV Payload Components

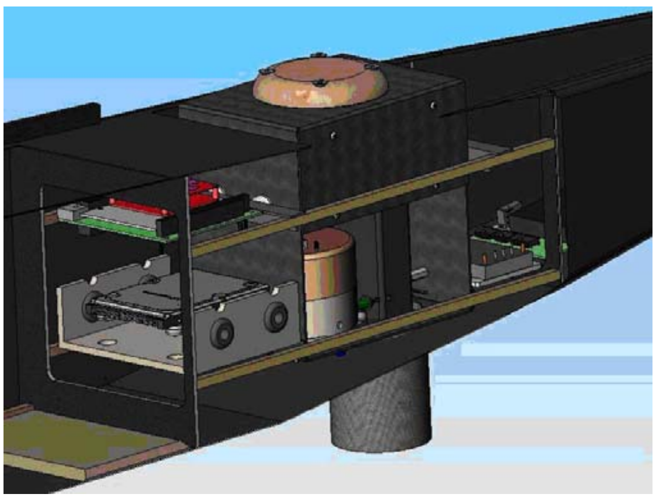

Figure 6 GI-Eye UAV Mechanical Assembly

The size, weight and power specifications for the GI-Eye UAV payload is included in Table 1. The camera and IMU can be either fixed in the aircraft or mounted inside a gimbal to allow GeoPointing to targets of interest. The individual components are described below.

Table 1 Payload Weight and Power Summary

Payload Component	Description	Weight (g)	Power (W)
Novatel GPS 511	GPS Antenna	145	0.125
Novatel OEM4-G2L	GPS Engine	56	1.600
BAE MIMU	IMU	539	16.850
Phoenix PC-1280/C	Digital Camera	176	1.500
Fujinon Fixed-Focal Lens	Lens	55	0.000
NAVSYS NIM Board	Interface Board	25	0.300
ADL MSM855-P738	SBC	250	13.000
Hitachi 7K100 60Gb	HDD	115	2.000
PC104 MSMPS104	Power Supply	105	
Cable Budget	Cable Budget	200	
Enclosure	Camera/IMU Platform	300	
Total		**1965**	**35.375**
		4.3	**lbs**

Figure 7 ARES Unmanned Air Vehicle

GPS Receiver and Antenna A NovAtel GPS receiver is being used for the GI-Eye. For high accuracy applications, we can use their dual frequency model to allow kinematic processing. In the configuration shown, an L1 model is used. Either Wide Area Augmentation System (WAAS) corrections or Differential GPS (DGPS) corrections from the Ground Station can be applied within the InterNav navigation solution.

IMU and NAVSYS Interface Module (NIM) InterNav supports a number of different IMUs. For this configuration, we selected the BAE Multisensor Inertial Measurement Unit.[7] The NIM is a customized board developed by NAVSYS that provides an adaptable interface between the IMU and single board computer through an RS232 or USB port. It also time synchronizes the IMU and GPS data.

Phoenix Digital Camera The digital camera uses a high resolution, color CMOS video sensor with a maximum resolution of 1280 x 1024 at 15 frames per second. The standard USB 2.0 interface is capable of transferring data at 480 Mbps and is integrated with a built-in frame buffer to prevent data loss. The camera is plug-n-play and supports Windows 2000/XP. The camera uses C mount lens with a ½" optical format. A variety of lens options are readily available from a number of manufactures ranging from fixed-focus 6 mm and smaller to 75 mm and zoom lens.

Flexibility in lens selection is a key aspect of the payload design because the lens characteristics define a number performance attributes of the system. In operational scenarios where the long distance target identification is important, a lens with a narrow field of view is required. If a significant overlap between images is important for image tracking or mosaic generation, a lens with a wider field of view may be required. Therefore, by simply swapping lenses on the digital camera, different mission objects can be accomplished with minimal effort.

Single Board Computer (SBC) and Ruggedized Hard Drive The SBC is the core processing and control element of the payload. It is a Pentium-M CPU based computer in a PC/104+ form factor, which provides a relatively high performance processing platform that is light weight with little power consumption. The integrated USB 2.0, RS232, and Ethernet ports provide a flexible means of interfacing the SBC with the payload components while the video and USB interfaces create a convenient development and debugging environment.

The SBC is paired with an 80 GB ruggedized hard drive. The large storage requirements of the digital imagery and the harsh environment of the UAV in terms of vibration and shock, limit the storage options. Although Flash drives are well suited for their small size and vibration and shock tolerance, the required storage capacity makes Flash drives are an expensive option. In addition, common laptop hard drives are unable to reliably function when subjected to the UAV's harsh vibration primarily generated by the UAV's engine. Consequently, the GI-Eye payload incorporates a ruggedized, laptop hard drive. The hard drive is further isolated from shock and vibration by placing it in a light weight mechanical fixture that suspends the hard drive on tuned, elastic belts.

Power Supply The GI-Eye system operates from a 12 VDC power supply. Total power consumption is 35.4 watts nominal and 56 watts peak. A DC/DC power supply is included in the package to power the subsystem components.

GeoReferenced Information Manager (GRIM)

The companion product to the GI-Eye is the GeoReferenced Information Manager. GRIM is developed based on an Enterprise Service architecture to provide tools to synchronize data between the UAV payload and the GRIM server and to provide management and intelligent search and retrieval of the image data. GRIM leverages the GI-Eye meta-data which provides the precise location and attitude of the sensor images to simplify and streamline feature extraction from the images. The precise sensor meta-data also eliminates the need for expensive and time consuming image processing for generating products such as mosaics or digital elevation models. In the following sections of this paper, the design of the GRIM Enterprise Server is described as well as a concept for implementation.

GRIM adopts an Enterprise Architecture to manage the GI-Eye information. The interface to the GI-Eye system is through a database onboard the UAV. The GRIM software architecture and interfaces to the GI-Eye is shown in Figure 8. GRIM was developed using Oracle Application Server and uses a Web Portal to provide the user interface. An Oracle database connection is used to synchronize the GI-Eye metadata and image thumbnails between the Oracle Express database in the GI-Eye and the GRIM database. This allows GRIM to use Web Services to prioritize the full image data for transfer across the downlink using FTP ("smart push"). Tools are included in the GRIM server to allow for location-based search and retrieval of the GI-Eye sensor data ("smart pull"). Users can access the GRIM viewing and targeting tools through a web browser. As discussed in the following section, GRIM is also designed to include embedded image processing functionality leveraging PCI Geomatics' embedded Geomatica OEM products. A summary of the features and benefits provided by the GRIM tools set is included in Table 2.

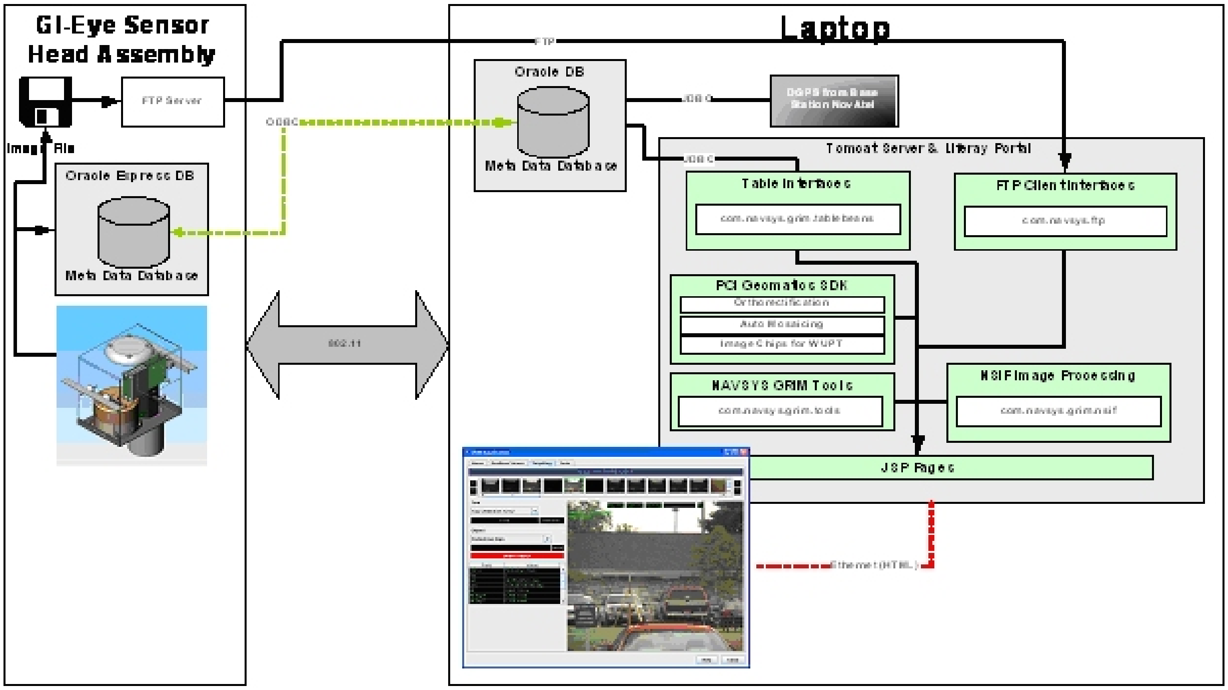

Figure 8 GI-Eye and GRIM Architecture

Table 2 Summary of GRIM Features and Benefits

Feature	**Conventional UAV Approach**	**GRIM Approach**
Imagery Downlink	Streaming video imagery downlinked. Compression needed due to bandwidth constraints compromises on image quality.	High resolution still-images downlinked. Real-time low resolution display provided for User Interface.
Search and Retrieval	Fast-rewind capability provided for review of past data – searches through time only.	Intelligent search and retrieval of imagery data based on time window and/or target coordinates.
Visual Display	Streaming imagery – requires trained operator to interpret "bird's eye" view	Real-time Mosaic generation – minimizes operator training by allowing overlay on existing tools such as FalconView or Google Earth
Targeting	Accuracy of targeting is generally poor due to low resolution metadata and reduced quality imagery	High accuracy targeting based on real-time georeferenced Mosaic (point and click user interface)

Auto-Mosaic Generation

The GRIM product has been designed to optionally include an auto-mosaicing function that can take the down-linked GI-Eye images and create a mosaic in near real-time. This allows the downlinked imagery to be displayed as a registered "over-head" image using existing tools such as FalconView or Google Earth.

The process of mosaicing is joining together two or more overlapping images to form a continuous composite image. The normal method of generating a mosaic is illustrated in Figure 9 and required intensive image processing to collect ground control points and compute a math model for use in orthorectifying the images and creating the mosaic. With the GI-Eye meta-data, the math model for each image can be explicitly calculated eliminating these time consuming steps.

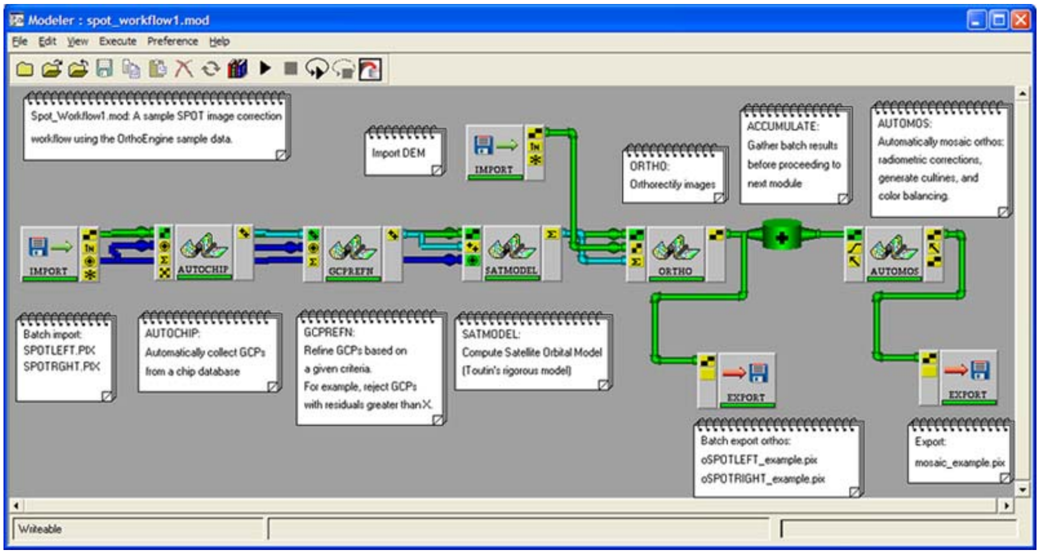

Figure 9 Mosaic generation using PCI Geomatics Tools[8]

Figure 10 shows the Auto-Mosaicing process that has been developed to be run on the GRIM Server using PCI Geomatics' Production Workflow products[8]. This uses a recursive process to orthorectify images from the GRIM database and use these to update the mosaic image. This process can be run in near real-time allowing an overhead view to be generated potentially within minutes of the images being collected. Examples of a mosaic generated from GI-Eye using this product are shown in Figure 11.

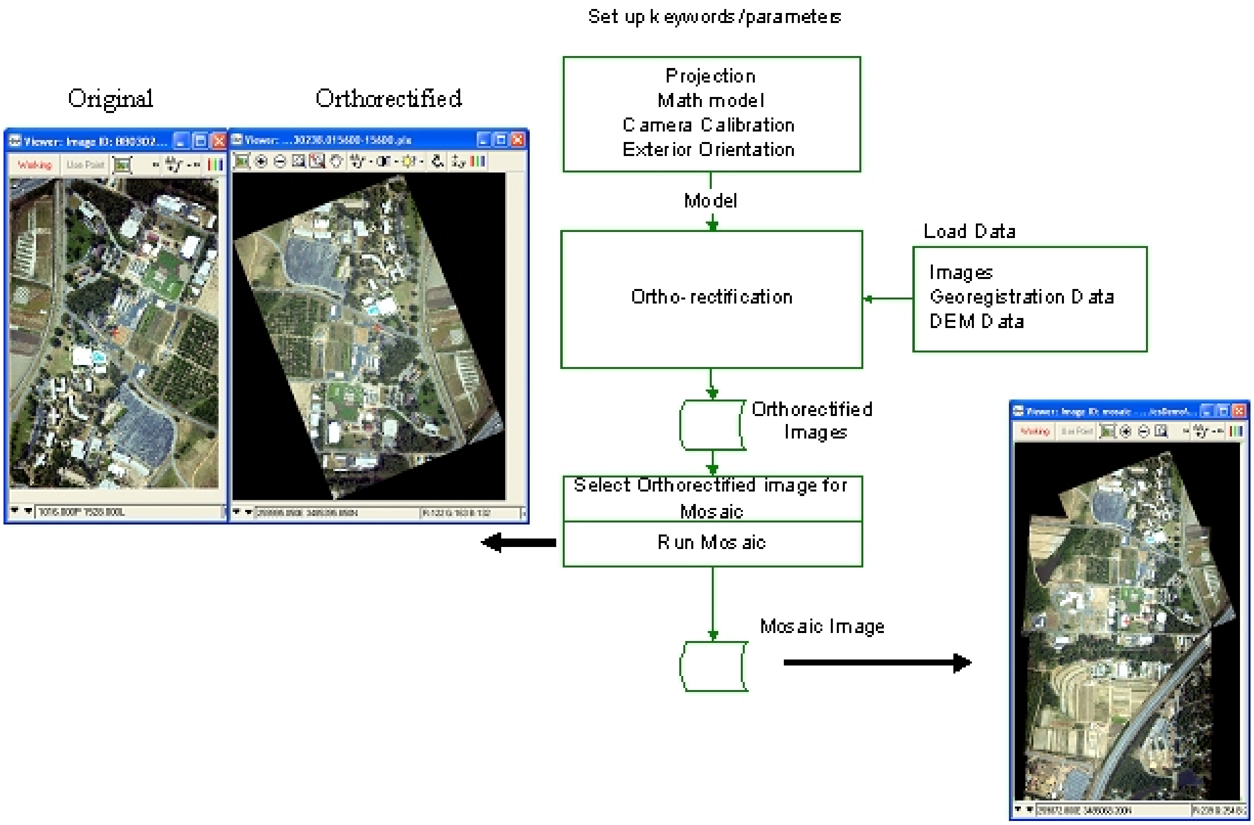

Figure 10 Auto-Mosaic Generation using PCI Geomatics Tools with GI-Eye meta-data

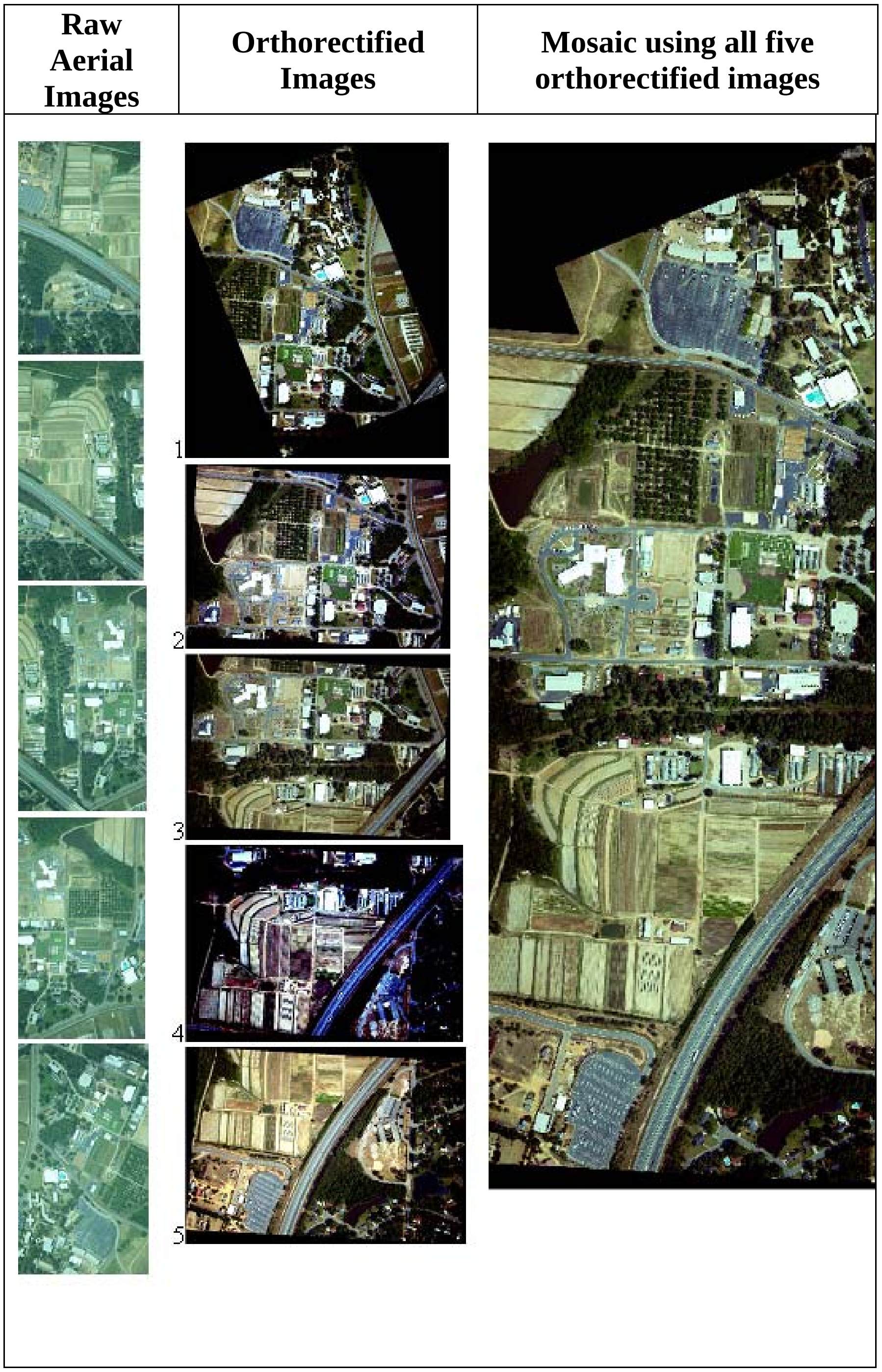

Figure 11 GI-Eye Raw Aerial Photos, Orthorectified Images, and Mosaiced Image

Concept of Operations for Near Real-Time Mosaic Generation
Using the GI-Eye and GRIM technology, it would be possible to generate in near real-time a continually updated registered mosaic with an overhead view of the area covered. A potential concept of operations for this capability is illustrated in Figure 12. A network of low cost persistent UAVs with GI-Eye payloads could be used to collect real-time registered imagery which is then downlinked to a central GRIM server. The imagery can be processed in near real-

time creating a registered overhead view in a format that can be used by Location Servers to provide a current view of the area covered by the UAVs.

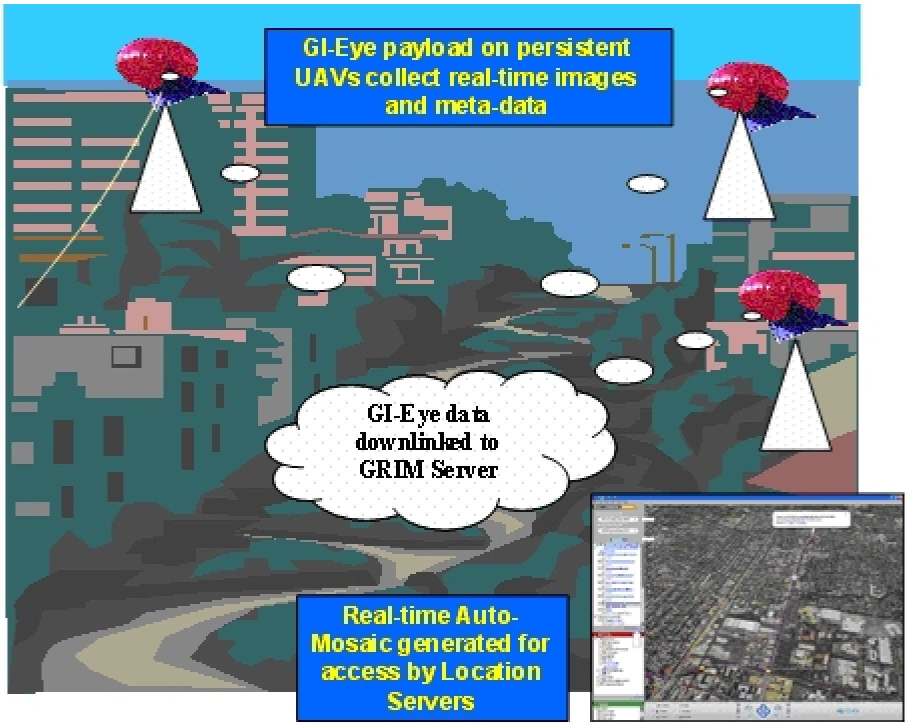

Figure 12 Urban Real-Time Auto-Mosaic Collection Concept of Operations

Conclusion

Near real-time dissemination of georeferenced imagery by a Location Server can benefit a number of military and civilian applications. The military would benefit from having access to imagery for situational awareness in a format that ground troops can easily use and can readily access using existing Web-based viewing tools. (For Harry Potter fans, this would provide the equivalent capability to the magical *"Marauders Map"*). For civil applications, the same type of situational awareness would benefit disaster recover efforts. For example, lives could have been saved in the Katrina disaster with the ability to provide responders precise geo-registered positions of victims with accurate images depicting their condition and environment. Forest fire hot zones will be able to be accurately identified and located quickly for special treatment. Police standoffs and hostage situations can be managed more efficiently with a better outcome because of real time precision image availability that precisely locates all parties.

For commercial Location Servers, near real-time imagery would address the desire of their customers for more current and accurate data. This would open up new market and service opportunities providing current information on road conditions, weather or even current events (Figure 13). Reducing the age of Location Server imagery from years to minutes would be a huge leap ahead for this exciting new technology. The GI-Eye and GRIM products are being provided by NAVSYS to enable this next generation advancement.

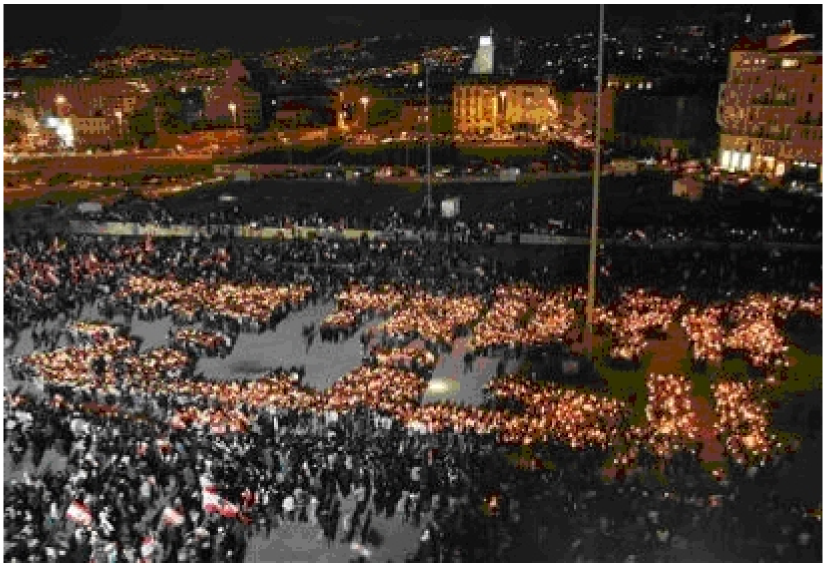

Figure 13 800,000 plus people in Lebanon spelling out the word "Truth" in English and Arabic

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